tion than that which exists at present can hardly fail to result, even though the degree of recognition of secondary school instruction may fall short of that which some desire.

H. P. Talbot
Massachusetts Institute of Technology

HIGH SCHOOL CHEMISTRY: THE CONTENT OF THE COURSE[1]

Every teacher in the high school of to-day finds himself in stimulating circumstances. He is obliged to question himself closely as to the part that his subject plays in the curriculum, for, at least in the large cities, the long-discussed change in the character of the high school is upon us. The reason for the change is found in a realization of the facts that in the past, high school education has been enormously wasteful; that eighty to ninety per cent. of our pupils do not complete the course; that only a small part of the remaining per cent. achieve the purpose for which the whole course has been framed, that of entering college. The evidence that the change has actually begun is found in the establishment of trade and vocational schools, in the frequent discussion of questions pertinent to these points, and in the statements of principals and superintendents that something must be done to stop the enormous educational waste; and in their declaration that the high school must meet real needs, must give the boy or girl the education that is best for him or her, as a member of the human group, with little reference to college entrance.

Among the changes that are coming from a recognition of these facts, we find the importance of science in the high school largely increased. The fact that it is science that has produced the great material advance of the past century makes it certain that in the further turning from formal to practical education, science will play a larger part. It is the purpose of this paper to inquire into the manner in which these changing conditions are reacting on the high school course in chemistry, and to discuss some of the considerations that are determining, or should determine, a new course of study. The speaker wishes also to discuss, in general, the problem of high school chemistry, presenting personal and perhaps even extreme points of view.

We may classify the various forces that are shaping the new course as external and internal. In the first class we find: (*a*) a lessening of the college influence, due to a realization of the necessity of educating for other purposes than college entrance; (*b*) a tendency to put chemistry earlier in the course and to give a second year of it; (*c*) what we may call the lay demand for practical education.

The lessened college influence will give to the body of secondary teachers not only greater freedom in the selection and arrangement of their material, but what is of even more importance, because it serves as a stimulus to their creative ability, a realization of the importance of their own great work and their responsibility for it. The lack of this kind of freedom is in part responsible for the condition that exists to-day when the high school, paying comparatively high salaries, can not get enough good men, while the college apparently has more than it needs at a smaller compensation. This is not the least of the evils that have resulted from the college domination of the high school. Others have often been pointed out and are well known. The course of study can never be adapted to the real needs of the high school so long as it is framed by the

[1] Presented at the second decennial celebration of Clark University, Worcester, Mass., September 16, 1909.

college, at the best a force operating at a distance, at the worst a power acting for needs it can not know. The college, as far as the high school was concerned, always had the idea of preparation, not growth, in mind. A thousand boys went through a course in chemistry whose nature was determined solely by the needs of the three or four who were to be trained to be expert chemists. It is often said at this point that the course which best prepares the pupil for advanced work is also best for every other boy. It is nearer the truth to say that the education which best meets the needs of the growing member of the human whole ought to be the best preparation for college.

Chemistry earlier in the course and perhaps a second year of it; the first of these conditions may bring dismay to many teachers; the second, delight to all, surely. Certainly some changes in the traditional course are necessary in teaching chemistry in the second year. On this point the speaker can refer to an experience covering nearly seven years. During all that time chemistry has been taught to some second-year students. At times fourth-year students and second-year students have been taking nearly the same course simultaneously in separate classes; at other times the two terms of students have been mixed in the same class. In both cases a certain degree of success with the second-year students has been obtained, even if we judge by no other standards than results of college entrance and state board examinations. Speaking for the moment from the standpoint of the college entrance syllabus, but little change is necessary to adapt the chemistry to second-year students. A less rigorous insistence on the philosophical development of the atomic and other hypotheses seems to be the most necessary item of change. In any case, as far as the ability of the student to comprehend is concerned, the difference between individuals is much greater than the difference between second- and fourth-year classes. The general average of work is considerably better in fourth-year classes, but this is explained largely by the dropping out of weak material.

To meet the demand for practical education, we find that there is a decided tendency to introduce into the high school a great deal more of chemical technology than there was in the older course. There are some who go so far as to say that the high school ought to give the pupil a means of earning his living; that chemistry should be taught so as to fit him for some direct employment in practical occupations. While admitting this as a possible ideal, the view implies such an extreme change in the character of the high school that it is not advisable to take it into consideration in the present discussion, except to admit that, given time, it would be possible to accomplish this result. Along with the demand for technical education, we find a tendency to fill the course with a great deal of matter that is associated with the home and every-day life. These two demands have come largely from without. They have done great good and have added much to the human interest of our science. We teachers are very prone to an academic point of view, and the stimulus has been a needed one. Yet with the good, there is some danger. There is a tendency in some quarters to emphasize the technological details of processes, to fill the discussion with technical terms, so that the pupils' talk bristles with tuyères and downcomers and the particular names of the many towers that find application in manufacturing chemistry. The chief evil of this kind of instruction is that it produces rather showy results, it seems to indicate more knowledge

than really exists. Moreover, a technical process of to-day is a very complicated thing. It is improved every year and we find to our discomfiture, on visiting the factory, that the process we have so carefully learned from the text-book differs in a hundred details from that actually employed.

The chemical interpretation of the ordinary phenomena of the household is a very interesting matter. Unfortunately many of these interpretations are very complex, others are unknown. Some are simple enough to be comprehended by a beginner, and certain food tests and the like can be taught so that the pupil can go through them in a more or less mechanical fashion. But surely these do not constitute a suitable vehicle for the transmission of that highly organized mass of knowledge and way of thinking which we know as chemistry. The intellectual and material advance that our science has brought to the world has not come from the knowledge of isolated test-tube reactions, but from the brilliant imaginings of the authors of its great hypotheses, from the realizations of its tremendous generalizations, from the perceptions of most deeply hidden relationships among the things that we call matter. If this that we teach our pupils is to bear the name of chemistry, it must give them at least a glimpse of these deeper things. Technological chemistry and household chemistry have a very proper place in the high-school course, but they should not be over emphasized. They afford the illustrative material which the good teacher will constantly use to give interest to his work by showing what good the science has brought to mankind. But a course composed almost wholly of such material, as has been proposed, would not be chemistry, and it would probably not be science. There would be an absence of principles, of relationships. A pupil might indeed learn that there exists a simple process for the manufacture of soda, but he would not share in any degree the kind of thinking that has made this and a thousand other processes possible. I hold that it is our chief duty to give him this kind of knowledge.

Coming then to the internal considerations which shall help shape our new course of study, we must inquire what high school chemistry should seek to accomplish for the pupil. One way of answering this question is by asking ourselves what it has done for us as individuals. We know that it has made us broader men and freer human beings, and it is fitting that we should seek to have our pupils attain in some degree this high end. Again, it is certain that one who has been through a good course in chemistry, who has learned the principles of chemical action, and comprehended the great laws that the science has revealed, looks upon the world about him in an altogether new way, so much so that with the increase in the general knowledge of science there is being produced a new type of world mind. Our pupils must be taught so that they shall share in this new world mind.

THE LABORATORY ASPECT OF THE COURSE

The course will continue to be based on experiment, the amount of laboratory work being limited only by the physical possibilities of the situation. The experiment will precede the class discussion in order that the pupil may conceive the things that he is talking about as realities. Chemical thinking can not go far without these definite conceptions. It requires images of real things, and it is this point of view that should determine the character of our laboratory work. There seems to be considerable difference of opinion, if not confusion, on this point.

There is the point of view which assumes that it is the purpose of the experiment to

prove the statement of the teacher or the text. Because there was so much that was bad in reliance upon authority in older types of education, it is felt that science must have none of this, but must accompany everything by rigorous proof. Following this method at its worst, the pupil is stimulated into a condition of perpetual doubt. He meets every statement with a but, and has rather the air of believing that some scientific charlatanry is being imposed on him. This is wrong; science does not have this attitude of perpetual doubt. It requires the most rigorous proof from discoveries of new things, but if each of us had demanded ocular demonstration at each step in our advancing knowledge, we should probably still be somewhere in the realm of descriptive inorganic chemistry. Moreover, it is a serious scientific mistake to let the pupil think that a single experiment performed under the ordinary condition of the beginner's laboratory proves much of anything. If it does, the speaker has seen many curious things proved in his time. Let us be frank: these experiments show at best the line of thought by which the proof is obtained. They illustrate the proof—they do not give it.

Nor does the theory that the pupil should, in the laboratory, rediscover the fundamental truths of the science, give us a right basis for experimental work. Followed to the extreme, this method soon reduces itself to an absurdity. Take, for example, the experiments of Lavoisier, which afford such an excellent starting point in the teaching of the subject. The pupil is given some metals and a balance, and is supposed, in an hour and a half, to rediscover what it took the best minds the world then possessed several centuries to accomplish. The fact the pupil's laboratory record, duly attested by the teacher, indicates that he independently accomplished this prodigious feat is a comment on the system. All that is done in this method at its best, is the arousing of the pupil's curiosity, which is later gratified by judicious suggestions at the proper moment from the teacher. There is no rediscovery; the line of thought has simply been retraced, and the big steps have been taken by the teacher. To be a discoverer you must be the author of your own curiosity. Another trouble with this method is that once committed to it the teacher is driven to curious round-about expedients to prevent the pupil's having knowledge in advance of the thing he is going to see. There are hundreds of instances where the pupil should have this knowledge in advance.

The speaker is more and more convinced that while the laboratory should to a certain extent seek to accomplish the things which the holders of two points of view consider desirable, its real purpose is to afford illustrative material, and by illustrative material he means that which will give concrete ideas—images—of things and processes. One might read hundreds of pages about chlorine, but if he had never seen it he would never know it. This is the great work of the laboratory method, to teach things and not literal symbols for them. We should seek this end, and let other considerations give way to it.

And we shall not neglect to exercise the pupil's scientific imagination. Chemical thinking requires this faculty. After he has been well grounded in the method of the laboratory, we shall want the pupil to learn to foresee chemical possibilities. The progress of the science has been by the working together of experiment and imagination, the one reacting upon the other and each suggesting in turn new steps in the advancing knowledge.

THE CLASS-ROOM ASPECT OF THE COURSE

It is no longer being framed exclusively

for the college entrance requirement; our course will not require us to cover so much material as it did formerly. Discussion of the rare elements and their compounds will give way to a more intensive study of those that show typical chemical actions, and establish the main lines of thought. We shall prefer to do this by reference to the things of the practical life where we can, but we will not go into the chemistry of foods, dyes, textiles and the like, knowing that this matter is far too complex for us to use in establishing the laws and relationships that are necessary for a comprehension of the science. We shall draw from every aspect of chemistry in our effort to establish the principles of chemical action. Our teaching may grow less descriptive and more dynamic. We may find it better to study types of chemical action than to study elements and compounds. As suggestion along this line, we might proceed, after reaching the definitions of chemical action, element and compound, to the general study of simple decompositions, using many experimental illustrations. We would bring in the ideas of stability and heat of formation. We would then proceed to direct combinations, simple replacements, and so on until finally the pupil would have a very good idea of the comparatively few types of chemical action. He would acquire incidentally a very practical descriptive knowledge.

Our course will necessarily continue to pay a large amount of attention to chemical theories, in order that we may have the means of seeing analogies and interpreting results. The mechanism of chemical changes is so far removed from direct observation by the senses that any attempt to comprehend these must be largely by aid of the imagination. The atomic theory has given us a splendid instrument for this purpose. We should retain it even if it had done nothing more than give us a system of chemical formulas, or made it possible to represent chemical actions by equations. Only one who has attempted to teach chemistry without the use of these symbols can fully appreciate what a tremendous aid they are. We shall therefore want to establish the atomic theory rationally, and to show how formulas are determined. This is perhaps the most difficult part of our work, but the fact that many pupils fail utterly to comprehend this matter is no ground for its omission from the course. There are many who succeed, and we must not forget that those who fail at least learn that such knowledge was acquired by human reasoning and patient experimenting. We should make our pupils feel that these theories are very practical things indeed, since it is largely by their aid that the science has advanced and brought material benefits to mankind.

We have in the past been given to considerable drill in certain types of chemical problems, largely because of the demands of college entrance examinations. There has been a good deal of mental gymnastics in the matter. These calculations should be taught in a less formal way; the laboratory is the best place to do it. Let the pupil calculate from the equations the quantities of substances he needs for his reaction, and then actually mix them in these proportions. Let him get practise in correcting gas volumes in the course of experiments involving simple gas measurements. Knowledge acquired in this way has a far greater staying quality than that obtained in formal class-room drill.

As we have already said, chemical technology will find a place in the course, but it must be taught by principle too. In the Solvay process, for example, it is more important that the pupil should get the idea of precipitation by differences in solubility than that he should know the mechanical details of the carbonating towers.

It is more important he should know that the process is only commercially profitable because the ammonia is recovered, thus getting hold of the principle of the utilization of by-products, than that he should know the factory terms for the machinery and operations. A good course in manufacturing equipment, in which different types of furnaces, towers and the like were grouped and compared might be of great practical and educational importance. But isolated bits of such information have no such value.

Our high-school chemistry might well include a treatment of more organic compounds than it has in the past. This knowledge can readily be acquired by reference to inorganic types. So many of the simpler derivatives of the hydrocarbons are things of every-day life that in order to include them we can afford to sacrifice some of the things of the traditional elementary course. The pupil needs, moreover, some intimation of the character and extent of the organic branch of the science.

In conclusion, the speaker feels that the best hope for the improvement of high school chemistry lies in discussions of the kind we are engaged in this morning. The experimental end of our work has been so new and interesting that much of our time has been spent on these matters. But the time is at hand when a reconsideration of the course as a whole in its general relations would be of benefit to the teaching of the elementary science.

JESSE E. WHITSIT
DE WITT CLINTON HIGH SCHOOL,
NEW YORK CITY

CHEMISTRY IN SECONDARY SCHOOLS[1]

IT is not necessary in a gathering such as this to recount the stages in the history of chemistry teaching in secondary schools —how, from the purely descriptive natural philosophy of the early college we finally essayed the teaching of chemistry and physics as sciences; how the miscellaneous encyclopedic instruction has been replaced by courses, designed, in these latter days, to develop power for the pupil rather than to impart knowledge.

The changes in content and method of formal secondary-school instruction have been brought about by the colleges; by advice, by supplying the teachers and most drastically, by the requirements for admission. While the bulk of the class might pass from the school and not be heard from again, the failure of a pupil to pass the college examination is quickly brought home to the teacher, so that the entrance examinations have become the standard of the school.

During the last fifteen years four syllabuses have been published which have decidedly affected the teaching of chemistry in schools; in 1894 that of the Committee of Ten, descriptive and general; in 1898 a Harvard syllabus, largely quantitative and scientific in method; in 1900, the syllabus of the College Entrance Examination Board, a plan for a course I hesitate to classify; in 1905, the last revision of the syllabus of the New York Department of Education, a historico-systematic course.

There is almost nothing in common to these four courses, and although the College Entrance Examination Board maintains and strengthens its hold upon the schools it has never, fortunately for the pupils, conducted its chemistry examination in accordance with its syllabus.

If we examine the texts to find what is being taught in high schools we find the chemistry text-books to be descriptive or theoretical; very few have successfully

[1] Presented at the second decennial celebration of Clark University, Worcester, Mass., September 16, 1909.